PB81-213795

Airborne Radiological Sampling of Mount St. Helens Plumes

Office of Radiation Programs-Las Vegas Facility, NV

Apr 81

U.S. Department of Commerce
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TECHNICAL REPORT DATA
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1. REPORT NO.	2.	3. RECIPIENT'S ACCESSION NO.
ORP-LVF-81-2		PB81 213795

4. TITLE AND SUBTITLE	5. REPORT DATE
Airborne Radiological Sampling of Mount St. Helens Plumes	April 1981
	6. PERFORMING ORGANIZATION CODE
7. AUTHOR(S)	8. PERFORMING ORGANIZATION REPORT NO.
Vernon E. Andrews	
9. PERFORMING ORGANIZATION NAME AND ADDRESS U.S. Environmental Protection Agency Office of Radiation Programs-Las Vegas Facility P.O. Box 18416 Las Vegas, Nevada 89114	10. PROGRAM ELEMENT NO.
	11. CONTRACT/GRANT NO.
12. SPONSORING AGENCY NAME AND ADDRESS SAME AS ABOVE	13. TYPE OF REPORT AND PERIOD COVERED
	14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

16. ABSTRACT

Particulate and gaseous samples for radiologial analyses were collected from the plumes created by eruptions of Mount St. Helens. The sampling aircraft and equipment used are routinely employed in aerial radiological surveillance at the Nevada Test Site by the Environmental Protection Agency's Environmental Monitoring Systems Laboratory in Las Vegas, Nevada. An initial sample set was collected on April 4, 1980, during the period of recurring minor eruptions. Samples were collected again on May 19 and 20 following the major eruption of May 18. The Environmental Protection Agency's Office of Radiation Programs analyzed the samples for uranium and thorium isotopes, radium-226, lead-210, polonium-210, and radon-222. Other laboratories analyzed samples to determine particle size distribution and elemental composition. The only samples containing radioactivity above normal ambient levels were collected on May 20. Polonium-210 concentrations in the plume, determined from a sample collected between 5 and 30 km from the crater, were approximately an order of magnitude above background. Radon-222 concentrations in samples collected from the plume centerline at a distance of 15 km averaged approximately four times the average surface concentrations. The small increases in radioactivity would cause no observable adverse health effects.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b. IDENTIFIERS/OPEN ENDED TERMS	c. COSATI Field/Group
Natural radioactivity Volcanic ejecta Air pollution		0807 1808 1302

18. DISTRIBUTION STATEMENT	19. SECURITY CLASS *(This Report)*	21. NO. OF PAGES
Release to public	Unclassified	18
	20. SECURITY CLASS *(This page)* Unclassified	22. PRICE

EPA Form 2220-1 (Rev. 4-77) PREVIOUS EDITION IS OBSOLETE

United States
Environmental Protection
Agency

Office of Radiation Programs
Las Vegas Facility
P.O. Box 15027
Las Vegas NV 89114

Technical Note
ORP/LVF-81-2
April 1981

Radiation

PB81-213795

EPA

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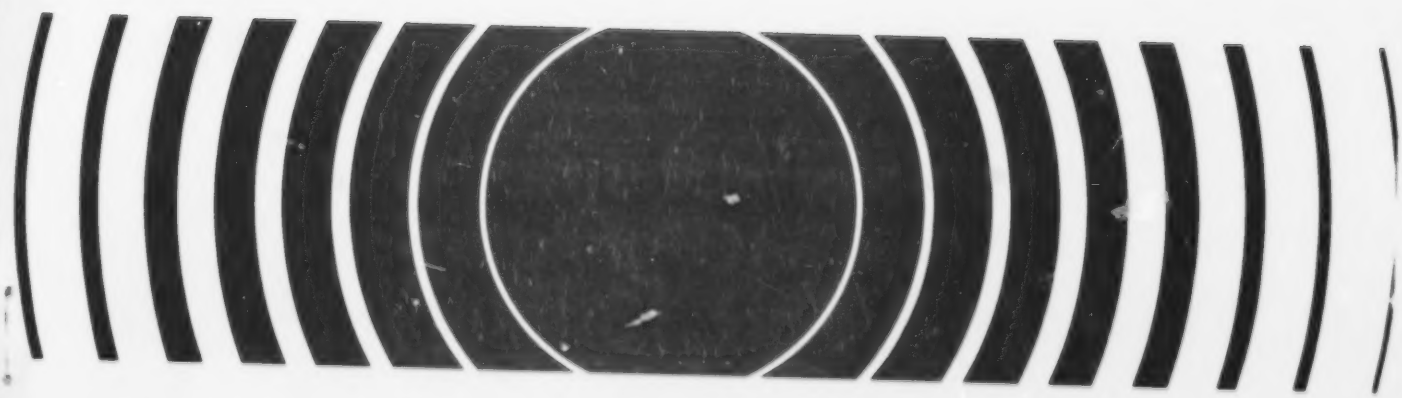

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Vernon E. Andrews

April 1981

Office of Radiation Programs - Las Vegas Facility
U.S. Environmental Protection Agency
Las Vegas, Nevada 89114

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PREFACE

The Office of Radiation Programs (ORP) of the U.S. Environmental Protection Agency (EPA) conducts a national program for evaluating exposure of humans to ionizing and nonionizing radiation. The goal of this program is to promote the development of controls necessary to ensure the public health and safety.

The eruption of the Mount St. Helens volcano constituted an unusual source of airborne radiation. In order to assess the potential radiation exposure to the public the EPA performed aerial sampling of the materials released. Although time, distance, and available funds limited the scope of this investigation, the results indicate that radioactivity associated with the eruption was not a threat to public health.

ORP encourages readers of the report to inform the Director, ORP, of any omissions or errors. Comments or requests for further information are also invited.

Donald W. Hendricks

Donald W. Hendricks
Director, Office of Radiation Programs
Las Vegas Facility

INTRODUCTION

On March 27, 1980 Washington State's Mount St. Helens returned to life from a 123-year dormancy. New life began as a strong gaseous venting which carried aloft a large amount of tephra eroded from older deposits in the mountain. This was followed by frequent eruptions of steam or steam and tephra interspersed with periods of quiet.

Evidence from other volcanoes has shown that eruptions may release greater concentrations of naturally occurring radionuclides than those usually found in the atmosphere. The State of Washington, concerned about possible radiation exposures to its residents, requested that the Environmental Protection Agency (EPA) determine the radiological hazard associated with the eruption. The Office of Radiation Programs-Las Vegas Facility (ORP) was asked to respond to the request.

An EPA-owned airplane which had been acquired and modified through Department of Energy (DOE) funding for cloud tracking and sampling in support of DOE's nuclear testing program was available at the EPA's Environmental Monitoring Systems Laboratory (EMSL) in Las Vegas. The EMSL made the airplane available to ORP, and DOE provided the airplane operating funds. The airplane departed Las Vegas on the morning of April 4, flew a 2-hour sampling mission during the afternoon, and returned to Las Vegas that evening.

A second mission was requested of EPA following the explosive eruption of May 18. The aircraft and crew departed Las Vegas at mid-morning on May 19 and flew a 2-hour sampling mission late that afternoon. The crew flew a final sampling mission on the morning of May 20.

This report describes the equipment and procedures used to collect and analyze the samples, and discusses the results in terms of potential effect on people.

EQUIPMENT DESCRIPTION

The aircraft used for the Mount St. Helens missions is a twin-turbo-prop Beechcraft BE8T. EPA had converted it to the BE8T configuration from a military C-45 and specially modified it for aerial tracking and sampling. EPA had equipped the aircraft to collect a variety of gaseous and particulate samples. Sampling personnel used a remote console in the aircraft cabin to operate and monitor external, wing-mounted pods.

A pod on one wing collects compressed air samples. The pod contains three stainless steel bottles, each with a 0.034-m^3 volume connected to a distribution manifold. The compressor stage of one of the aircrafts turbine engines fills the bottles, and limiting orifices control the flow rate. Sampling rates of 0.0075, 0.0145, and 0.022 cubic meters per minute (m^3/min) are selectable at the console.

A pod on the other wing collects particulate samples using a filter sampler and an electrostatic precipitator sampler. The filter sampler simultaneously collects four samples on 10-cm diameter filters. Only one set of filter samples can be collected per flight. A venturi mass flow meter measures air flow. Sampling rates for the pod filter sampler are approximately 0.6 m^3/min using Microsorban polystyrene fiber filters and 0.8 m^3/min using glass fiber filters. The electrostatic precipitator sampling system consists of two tubes. Each tube, 3 feet long by 3 inches in diameter, has a wire mounted along the tube axis. The wire is electrically insulated from the tube wall and is maintained at approximately 18 kv negative with respect to the tube wall. A venturi mass flow meter again measures air flow. The electrostatic precipitator sampler operates at about 1.3 m^3/min through each tube.

Because the sampling pods are inaccessible during flight, additional samplers were used in the aircraft cabin to collect several samples during a mission. Air entering the sample probe at the aircraft nose passed through a plenum in the cabin. An air sampler using a 7- by 10-inch filter collected samples from the plenum. Crew members used a second nose probe discharging into the cabin to collect short term grab samples of air in 30-liter Tedlar

bags. The cabin filter sampler has a flow rate of about 2.5 m^3/min with glass fiber filters and 2.0 m^3/min with Microsorban filters.

MISSION DESCRIPTIONS

April 4, 1980

The sampling team reached Mount St. Helens at 1:30 p.m., about 90 minutes after an earthquake of magnitude 4.5 had occurred. An eruption of gas and dust lasting for about 45 minutes followed the earthquake. As the team approached from the west they saw a light brown dust plume extending several miles to the northwest from near the Goat Rocks region on the northwest slope. The plume top was at about 3050 meters (10,000 feet) above mean sea level (MSL). The maximum visible dust density in the plume was at about 2130 meters (7,000 feet) above MSL. A small cloud of water vapor was observed near the summit on the east side, but the dust plume was the major visible evidence of an eruption.

An east-west sampling pattern was flown across the dust plume at the altitudes and locations shown in Table 1. At each altitude the team collected cabin filter and bag samples, while the wing pod particulate samplers operated during the entire mission.

May 19, 1980

The EPA aircraft arrived in Portland, Oregon in the early afternoon of May 19 and flew a sampling mission from 1500 to 1700 hours.

During the sampling mission the ash plume was observed to be rising to approximately 3050 m above MSL at the east (downwind) lip of the crater. As the ash plume moved easterly, the visible top rose slowly. The plume top rise was estimated to be less than 300 m within the first 50 km from the volcano. The plume centerline was visually estimated to be at about 2750 m above MSL. The south edge of the visible plume was fairly well defined along an east-west line from the crater across the north slope of Mount Adams. Mount Adams lies approximately 55 km due east of Mount St. Helens. Considerable resuspended ash from the area north of the volcano and low clouds to the north, combined with the more diffuse release issuing from the blown-out north face of Mount

St. Helens, made it difficult to estimate the northern boundary of the ash plume.

Samples were collected along the south edge of the plume from about 8 to 55 km east of Mount St. Helens. The plume was penetrated at a shallow angle near the volcano with the east end of a sampling run being 3 to 5 km inside the plume. Some passes were also made at altitudes as low as 1750 m in the region south and west of Mount Adams through low-lying clouds of ash drifting over the area. The sandblasted paint and windshield of a plane which had flown under the plume earlier in the day persuaded the team to avoid the more dense portions of the plume.

TABLE 1. APRIL 4 SAMPLING SUMMARY

Time Interval (PST)	Altitude (ft. MSL)	Number of Passes	Distance From Goat Rocks	Samples Collected	
				Filter	Bag
1316-1321	7,000		50-80 km south	GF[a]	
1323-1328	7,000		15-40 km south	MS[b]	2
1336-1343	10,000	3	3 km north	MS	2
1347-1353	9,000	3	3 km north	GF	2
1357-1420	8,000-7,000	6	3 km north	MS	3
1423-1445	7,000	7	3 km north	GF	2
1450-1515	7,000	7	1.5 km north	MS	2
1316-1515	All[e]	26	1.5-3 km north	Pod[c]	
1316-1515	All[e]	26	1.5-3 km north	Precip.[d]	
1520	6,000		15 km south		1

a. GF = 7- by 10-inch glass fiber filter
b. MS = 7- by 10-inch Microsorban polystyrene fiber filter
c. Set of four 10-cm filters
d. Electrostatic precipitator
e. Collected on all sampling passes at 10,000, 9,000, 8,000, and 7,000 ft.
f. Ambient samples collected south of Mount St. Helens.

The wing pod particulate samplers were operated continuously from 1500 to 1700 hours. One cabin filter sample was collected from 1503 to 1555 and second one was collected from 1600 to 1700 hours. Two of the compressed air

bottles in the wing pod were filled simultaneously by periodic collections while inside the plume between 1510 and 1630 hours. Table 2 shows the collection data for the grab bag samples collected.

TABLE 2. MAY 19 GRAB BAG SAMPLE COLLECTION DATA

Time	Location	Altitude (m,MSL)
1547-1548	8 km west of Mount Adams	2770
1549-1550	8 km north of Mount Adams	2770
1614-1615	8 km south of Mount Adams	2130
1624-1625	16 km east of Mount St. Helens	1750
1630-1632	9-16 km west of Mount Adams	2130
1638-1640	15-20 km west of Mount Adams	2280

May 20, 1980

By the morning of May 20 the weather had deteriorated with most of the area under clouds. When the team arrived at the volcano at 0920 hours, a cloud layer 300 to 400 m thick lay over Mount St. Helens, with the base slightly below the crater lip. A dense white plume rose through the cloud layer, topping out at about 300 m above the cloud. As the plume cooled and the steam dissipated - within 1 km of the downwind crater lip - a tan-colored ash plume remained. This ash plume descended, then leveled off with the top at about 2700 m above MSL. Whereas on the 19th the southern plume edge was about due east from the volcano, passing over the north flank of Mount Adams, now it passed 15 to 20 km north of Mount Adams. The plume centerline had shifted from east-northeast to northeast.

Decreased ash density allowed a safe flight through the plume. A series of passes were made diagonally across the plume on a path southwest to north-east, between points on the southern edge of the plume about 5 km east of the east lip of the crater and about 30 km north-east on the north edge. On the final pass to the southwest the flight path was altered to fly inbound along the plume centerline to within about 8 km of Mount St. Helens, then counter-clockwise around the crater on that radius until exiting the ash cloud north of the mountain. All passes were flown at 2440 to 2650 m above MSL.

The pod filter sampler was operated continuously during the entire sampling flight from 0933 to 1026 hours. One cabin air filter sample was collected from 0936 to 0950 and a second was collected from 0951 to 1026. A compressed air sample was collected intermittently in the bottle remaining in the wing pod from 0933 to 1053. Four grab bag air samples were collected from near the plume center, 15 to 20 km from Mount St. Helens, 2440, 2540, 2560, and 2650 m above MSL.

ANALYSIS OF SAMPLES

The samples were divided among three laboratories for a variety of analyses. Some of the grab bag and compressed air samples were sent to the Washington State University Air Resources Laboratory for use in their program of measuring naturally occurring halocarbons. Some of the particulate filter samples and one electrostatic precipitator sample were sent to Los Alamos Scientific Laboratory for particulate sulfate analysis. The remainder of the samples were analyzed for naturally occurring radioactivity and elemental abundance at the EPA laboratory in Las Vegas. This report contains the results of the EPA analyses.

The radioactivity reported for each sample is the net radioactivity plus or minus twice the standard deviation (2s). The net radioactivity is the gross sample radioactivity minus counter background, and for filter samples, minus an average value for the radioactivity content of a blank filter. The standard deviation is based only on the random variations inherent in radioactivity counting and is propagated through the various steps to the net result.

Due to the low levels of radioactivity encountered, an occasional sample is reported with a net negative result. Of course, there is no negative radioactivity. In these cases, as with all others, the net result must be considered along with the 2s uncertainty.

April 4, 1980, Samples

Radon in the grab bag samples was removed from the rest of the air using a combination cryogenic and gas chromatographic technique. The radon plus

carrier gas was collected in a gas scintillation cell and counted for alpha activity after allowing several hours for ingrowth of radon progeny. All radon-222 concentrations were below the lower limits of detection (LLD) of 30 to 40 picocuries per cubic meter (pCi/m^3).

The LLD is defined (Harley) as the smallest concentration of radioactive material sampled that has a 95 percent probability of being validly detected.

$$LLD = \frac{4.66\ S_b}{2.22 \times E \times S}\text{, where;}$$

$4.66 = 2\sqrt{2}\,k$, where k is the value for the upper percentile of the standardized normal variate corresponding to the preselected risk for concluding falsely that activity is present (α) = 0.05

S_b = standard deviation of the background

2.22 = disintegrations per minute/pCi

E = fractional counting efficiency

S = sample size

Two cabin filter samples and two of the four filters from the pod sampler were analyzed for radioactive particulates. One cabin sample was collected on three passes across the dust plume at 2440 m (8,000 feet) MSL and three passes at 2130 m (7,000 feet) above MSL. The other sample was collected on seven passes across the plume at 2130 m above MSL. The filters were dissolved for radiochemical separation and analysis for the elements of interest. Neither cabin filter sample contained naturally occurring radionuclides significantly greater than the quantities measured in blank filters. The two filters from the pod sampler were analyzed independently and the results for each radionuclide were summed. The calculated concentrations, assuming that all of the net radioactivity was collected while actually in the plume, are presented in Table 3.

May 19 - 20, 1980 Samples

Whole air samples from the grab bags and one compressed air bottle from May 19 were transferred directly into the gas scintillation cells without concentrating the radon. Table 4 shows the measured concentrations at ambient conditions of samples collected on both days. Only one sample, collected at

0944 hours on May 20, had a measured concentration greater than twice the standard deviation.

TABLE 3. POD FILTER SAMPLE RADIOACTIVITY CONCENTRATIONS APRIL 4, 1980

Radionuclide	Concentration (pCi/m^3)*
Uranium-234	0.008 ± 0.004
Uranium-238	0.008 ± 0.005
Thorium-230	0.076 ± 0.014
Thorium-232	0.008 ± 0.005
Radium-226	0.059 ± 0.017
Polonium-210	0.008 ± 0.021

* Concentration plus or minus two standard deviations based on counting statistics only.

The samples collected each day were collected under similar conditions. Therefore, the average concentration was calculated for each day. The associated uncertainty is twice the standard error of the mean. An average concentration of 290 ± 260 pCi/m^3 was calculated for May 19. The average concentration calculated for May 20 was 390 ± 250 pCi/m^3.

TABLE 4. RADON-222 CONCENTRATIONS MAY 19 AND 20, 1980

Date	Time	Altitude (m,MSL)	Location	Concentration (pCi/m^3)*
5/19	1547	2770	8 km west of Mount Adams	130 ± 530
5/19	1549	2770	8 km north of Mount Adams	330 ± 570
5/19	1614	2130	8 km south of Mount Adams	500 ± 710
5/19	1624	1750	15 km east of Mount St. Helens	-300 ± 600
5/19	1638	2290	15 km west of Mount Adams	620 ± 720
5/19	1510-1630	1750-2770	Compressed air; integrated throughout mission	470 ± 650
5/19			Average of all samples	290 ± 260
5/20	0941	2650	30 km NE of Mount St. Helens	410 ± 450
5/20	0944	2530	15 km NE of Mount St. Helens	600 ± 510
5/20	0952	2440	15 km NE of Mount St. Helens	300 ± 520
5/20	0955	2560	15 km NE of Mount St. Helens	240 ± 530
5/20			Average of all samples	390 ± 250

* Concentration plus or minus twice the standard deviation based on radioactivity count or twice the standard error of the mean for averages.

One pod filter sample from each day was analyzed as before for natural radioactivity. The observed concentrations of radioactivity at ambient conditions are shown in Table 5. On the whole they did not differ significantly between nuclides or between filters for the same nuclide. The one exception was polonium-210 on the sample collected May 20. The concentration of 0.039 ± 0.019 pCi/m^3 is 13 times the mean surface air concentration of 0.003 pCi/m^3 (NCRP).

TABLE 5. POD FILTER SAMPLE RADIOACTIVITY CONCENTRATIONS MAY 19 AND 20, 1980

Radionuclide	Concentration (pCi/m^3) May 19	May 20
Uranium-234	0.012 ± 0.006	-0.001 ± 0.008
Uranium-238	0.009 ± 0.008	-0.003 ± 0.006
Thorium-230	0.000 ± 0.003	0.004 ± 0.007
Thorium-232	0.000 ± 0.003	-0.001 ± 0.005
Polonium-210	0.008 ± 0.010	0.039 ± 0.019
Uranium decay chain average (average ± standard error of mean)	0.007 ± 0.005	0.000* ± 0.003

* Excluding Polonium-210. Thorium-232 is not a member of the uranium chain.

For comparison, Table 6 shows the concentrations of radioactivity in ash fallout samples collected by the State of Washington Environmental Radiation Program and a private citizen. It can be seen that the ash collected on April 4 exhibited no significant difference between polonium-210 and the other members of the uranium decay chain. All of the samples collected following the May 18 and May 25 eruptions were similar to each other, with polonium-210 concentrations about twice the average of the other uranium chain members. Particulates collected on the electrostatic precipitator May 20 were removed by washing with deionized water. The particles in the wash water were sent to LFE Environmental Analysis Laboratories in Richmond, California, for particle size analysis. LFE resuspended the particles using ultrasonic agitation for 10 minutes. An aliquot was optically sized using a Leitz phase contrast microscope at 500X magnification. The results are shown in Table 7. The volume distribution best fits a normal distribution with a mean diameter of

23.5 micrometers (μm) and standard deviation of 8.5 um. The number distribution appears bimodal with 85.6 percent of the particles represented by a log-normal distribution having a geometric median diameter of 0.65 μm and geometric standard deviation of 1.54. The other 14.4 percent of the particles have a geometric median diameter of 3.6 μm a geometric standard deviation of 2.92.

TABLE 6. RADIOACTIVITY CONCENTRATIONS IN ASH FALLOUT

Date	Location	Uranium-238	Uranium-234	Thorium-230	Polonium-210
April 4	North side Mount St. Helens	0.50 ± 0.21	0.30 ± 0.07	0.36 ± 0.08	<0.36
May 18	Morton, WA	0.39 ± 0.11	0.38 ± 0.11	0.33 ± 0.08	1.0 ± 0.2
May 18	Wenatchee, WA	0.47 ± 0.14	0.42 ± 0.13	0.41 ± 0.09	0.78 ± 0.19
May 19	Royal City, WA	0.51 ± 0.12	0.43 ± 0.12	0.41 ± 0.09	0.62 ± 0.31
May 19	Boise, ID	0.39 ± 0.11	0.54 ± 0.13	0.49 ± 0.12	0.95 ± 0.19
May 25	Centralia, WA	0.44 ± 0.11	0.40 ± 0.11	0.44 ± 0.09	1.2 ± 0.3

TABLE 7. AIRBORNE PARTICLE SIZE ANALYSIS MAY 20, 1980

Size Range µm	Number of Particles	Numerical Percent	Cumulative Numerical %	Volume Percent	Cumulative Volume %
0.3 - 0.6	669	37.25	37.25	0.016	0.016
0.6 - 0.9	504	28.06	65.31	0.054	0.070
0.9 - 1.2	249	13.86	79.18	0.073	0.143
1.2 - 1.8	116	6.46	85.63	0.100	0.243
1.8 - 2.5	83	4.62	90.26	0.21	0.453
2.5 - 3.5	45	2.51	92.76	0.31	0.763
3.5 - 5.0	28	1.56	94.32	0.55	1.31
5.0 - 7.0	28	1.56	95.88	1.54	2.85
7.0 - 10.0	24	1.34	97.22	3.76	6.61
10.0 - 14.0	23	1.28	98.50	10.13	16.74
14.0 - 20.0	14	0.78	99.28	17.53	34.27
20.0 - 28.2	10	0.56	99.83	35.68	69.95
28.2 - 39.8	3	0.17	100.00	30.05	100.003
Total	1796				

DISCUSSION AND CONCLUSIONS

The aerial samples collected from the dust plume following the small eruption on April 4 contained low levels of naturally occurring radionuclides. The isotopic ratios indicate that composition of the airborne dust was similar to that of crustal rock. The airborne radioactivity was comparable to what might be found under any severely dusty condition, such as a dust storm. No evidence was found of enrichment of gaseous or volatile radionuclides - particularly including radon-222 and polonium-210.

Heavy ash concentrations on May 19 prohibited sampling deep within the plume. The particulate samples collected along the plume fringes yielded results similar to those collected on April 4. Radon-222 results may indicate some elevation above ambient, however, measured concentrations had such large standard deviations and were so variable that no definite increase can be inferred.

A less dense plume on May 20 permitted collection of aerial samples while traversing the plume. The only significant particulate radioactivity measured was polonium-210. Polonium is the most volatile of the elements, other than radon, in the uranium series. Polonium-210 is commonly found to be enriched in particulate emissions from mineral smelting and calcining operations that have temperatures comparable to that of magma. Because polonium-210 is released as a vapor and condenses to a particulate, it is usually associated with the smaller particle sizes (EPA). This association could explain the difference observed between the polonium-to-uranium chain ratios of the aerial sample and ash fallout. Possibly, the polonium-210, associated with smaller particles, remained airborne as the coarse particles fell to earth.

J. S. Fruchter et al. at Battelle's Pacific Northwest Laboratory reported increasing polonium-210 concentration with decreasing particle size on ash collected at Moses Lake. They found 41 percent of the polonium-210 was associated with particles less than 3.5 μm diameter - or with less than one percent by volume of the particles. The Battelle data also showed that the polonium-210 concentration in particles greater than 3.5 μm was the same as

what might be expected in normal rock. It follows that almost all of the excess polonium-210 in the aerial samples at Mount St. Helens was also associated with the small particles. Therefore, although most of the airborne particulate mass was too large to be inhaled, most of the polonium-210 was respirable.

Radon-222 was significantly above the system detection limit in one sample collected on May 20. That sample was collected at 2530 m above MSL, approximately even with the crater lip. The average of the four samples from the 20th analyzed for radon-222 is believed to be a reasonable estimate of the plume concentration at 15 km from Mount St. Helens. This average of 390 pCi/m^3 is about 4 times the average radon-222 concentration of 100 pCi/m^3 in the northern hemisphere at ground level (NCRP). The radon-222 levels measured during the continuous release following the May 18 explosion were too low to be considered a hazard. They would, however, have raised the airborne concentrations of radon and its decay products at ground level in the plume.

The short-term exposure of the affected population to the plume from Mount St. Helens would have resulted in a small increase above the annual radiation dose due to naturally occurring radioactivity. For most of the radioactive elements present the additional dose was comparable to that received by being in a dust storm for several days. In the case of polonium-210 and the radioactive decay products of radon-222, both of which were released in greater quantity than the other radionuclides, the radiation doses were probably less than the dose which would have been received during a month or two of exposure to those radionuclides under normal background conditions.

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